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### 3.0 RECYCLED URANIUM MASS FLOW

#### 3.1 RECYCLE URANIUM RECEIPTS AND SHIPMENTS

The recycled uranium includes receipts and shipments received and processed at the various facilities after 1961, for this report. The major facilities that received or shipped materials include Oak Ridge (K-25 and Y-12), Portsmouth, Paducah, RMI, West Valley, Weldon Spring, Hanford, Savannah River, Rocky Flats, Idaho, and other sites. The WVDP processed spent nuclear fuel and is a source site of recycled uranium and therefore will show no receipts of recycled uranium.

##### 3.1.1 FEMP

The FEMP facility processed uranium materials that were part of the recycle effort. The Uranium Recycle receipts and shipments are summarized by facility/location as follows:

**TABLE 3-1A  
FEMP RECEIPTS AND SHIPMENTS OF RECYCLED URANIUM**

Facility/Location	Enriched Receipts (MTU)	Enriched Shipments (MTU)	Normal Receipts (MTU)	Normal Shipments (MTU)	Depleted Receipts (MTU)	Depleted Shipments (MTU)
Oak Ridge (K-25)	1,062.2	4	246.1	13.4	1,413.3	0.3
Oak Ridge (Y-12)	88.1	31.7	18.4	108.0	21.4	9,390.5
Portsmouth	1,172.8	145.9	541.4	701.3	<0.1	1.2
Paducah	7,696.7	7,219.8	131.1	25,914.2	51,872.8	3,554.8
RMI	17,136.5	26,210.6	4,997.7	5,235.6	35,678.7	35,875.3
WVDP	466.2	--	12.9	<0.1	142.1	0
WSSRAP	810.9	837.5	44,547.4	10,133.3	5.1	2.8
Hanford	19,652.3	17,467.5	2,635.1	30,788.3	481.7	125.2
Savannah River	3,423.8	3,971.2	1,298.7	3,982.8	1,669.7	24,193.6
Rocky Flats	1.3	2.1	4.0	<0.1	1,318.2	5,352.5
Idaho	1.6	0	<0.1	0.5	0.3	83.9
Other Sites	8,668.3	4,415.3	35,217.4	17,975.2	4,249.8	15,491.0
<b>Total</b>	<b>60,180.7</b>	<b>60,305.6</b>	<b>89,649.2</b>	<b>94,852.8</b>	<b>96,853.2</b>	<b>94,071.1</b>

Additional details for receipts are included in Appendix A. Appendix B includes additional details on shipments. Table 3-1A shows total shipments for normal uranium in excess of receipts, this is a result of tracking the receipts and shipments after February 1961.



### 3.1.2 RMI

The RMI facility processed uranium materials that were part of the recycle effort. The Uranium Recycle receipts and shipments can be summarized as:

**TABLE 3-1B**  
**RMI RECEIPTS AND SHIPMENTS OF RECYCLED URANIUM**

Facility/Location	Enriched Receipts (MTU)	Enriched Shipments (MTU)	Normal Receipts (MTU)	Normal Shipments (MTU)	Depleted Receipts (MTU)	Depleted Shipments (MTU)
Oak Ridge (Y-12)	--	--	--	--	240.3	224.2
Paducah	--	--	--	--	--	3.0
FEMP	25,214.9	15,973.3	5,235.6	4,970.2	35,878.7	35,855.7
WSSRAP	--	--	--	2.2	--	--
Hanford	112.5	9,296.3	0.4	209.4	--	12.4
Savannah River	--	--	--	--	<0.1	<0.1
Rocky Flats	--	--	--	--	9	8.8
Other Sites	--	0.2	<0.1	<0.1	10,030.5	9,618.7
<b>Total</b>	<b>25,327.4</b>	<b>25,269.8</b>	<b>5,236.0</b>	<b>5,181.8</b>	<b>46,158.5</b>	<b>45,722.7</b>

### 3.1.3 WVDP

Since Spent Fuel is out of the scope of this project, there were no reportable receipts of Recycled Uranium at the WVDP. However, during the reprocessing of materials a total of 620 metric tons of uranium was recovered (recycled) and this material was shipped to the FEMP, as liquid uranyl nitrate, for additional processing. In addition, West Valley shipped an additional MTU of high assay, ~90% U-235 to the Y-12 plant of Oak Ridge. The quantities of "Uranium Received" were based on shipper's data, i.e., theoretical calculations of the uranium contained in the fuel. There were a total of 27 processing campaigns performed at West Valley, however, only the first 26 campaigns reprocessed intact reactor fuel. The last campaign involved processing liquid residues received from Nuclear Fuels Services Facility in Erwin, Tennessee, generated during the fabrication of fuel for the Southwest Experimental Fast Oxide Reactor (SEFOR). This information is presented in the following table:



**TABLE 3-1C**  
**WVDP RECEIPTS AND SHIPMENTS OF RECYCLED URANIUM**

Facility/Location	Enriched Receipts (MTU)	Enriched Shipments (MTU)	Normal Receipts (MTU)	Normal Shipments (MTU)	Depleted Receipts (MTU)	Depleted Shipments (MTU)
Oak Ridge, Y-12	--	1.2	--	--	--	--
FEMP	--	463.2	--	12.9	--	142.1
<b>Total</b>	--	<b>464.4</b>	--	<b>12.9</b>	--	<b>142.1</b>

#### 3.1.4 WSSRAP

The following table summarizes the receipts at the Weldon Spring Site.

**TABLE 3-1D**  
**WSSRAP RECEIPTS AND SHIPMENTS OF RECYCLED URANIUM**

Facility/Location	Enriched Receipts (MTU)	Enriched Shipments (MTU)	Normal Receipts (MTU)	Normal Shipments (MTU)	Depleted Receipts (MTU)	Depleted Shipments (MTU)
FEMP	837.5	810.8	10,133.3	44,547.4	2.8	5.1
Other Sites	5.1	23.1	60,405.1	29,331.0	29.2	87.2
<b>Total</b>	<b>842.6</b>	<b>833.9</b>	<b>70,538.4</b>	<b>73,878.4</b>	<b>32.0</b>	<b>92.3</b>

### 3.2 CONSTITUENT RECEIPTS AND SHIPMENTS

#### 3.2.1 FEMP

The constituent receipt and shipment information for the FEMP has been developed utilizing historical data and information from the Material Control and Accountability (MC&A) System as documented in Section 3.1.1, recycled uranium receipts and shipments. The recycled uranium data were carefully analyzed and using process knowledge, representative constituent values determined based on data sources and subgroups presented in Table ES-5A. Using the data from the tables presented and discussed above, the FEMP Recycled Uranium Project team developed a detailed spreadsheet which quantifies the "Calculated mass constituents" for Pu-239, Np-237 and Tc-99 for all normal, depleted and enriched shipment of recycled uranium at the FEMP. This spreadsheet is presented in detail in Appendix F, Tables F.5-1A, F.5-1B, F.5-5, and F.5-6 and summarized below.



**TABLE 3-2A**  
**FEMP SUMMARY OF CALCULATED CONSTITUENT MASSES**

Isotopic Range	RU Quantity (MTU)	Calculated Constituent Mass (Grams)		
		Pu-239	Np-237	Tc-99
Enriched – Receipts	60,180.7	207.9	19,047.5	328,740.2
Normal – Receipts	89,649.2	4.1	3,025.9	1,197.4
Depleted – Receipts	96,853.2	5.7	3,668.7	2,060.5
<b>Total – Receipts</b>	<b>246,683.1</b>	<b>217.7</b>	<b>25,742.1</b>	<b>331,998.1</b>
Enriched – Shipments	60,305.6	180.9	20,769.3	333,698.9
Normal – Shipments	94,852.8	7.7	5,683.8	2,249.3
Depleted – Shipments	94,071.1	2.4	424.8	1,541.3
<b>Total – Shipments</b>	<b>249,229.5</b>	<b>191.0</b>	<b>26,877.9</b>	<b>337,489.5</b>
Enriched – NM Inventory	801.3	14.4	531.1	1,858.4
Normal – NM Inventory	193.4	0.7	84.2	308.9
Depleted – NM Inventory	2,807.1	<0.1	13.0	5.1
<b>Total – NM Inventory</b>	<b>3,801.8</b>	<b>15.2</b>	<b>628.3</b>	<b>2,172.4</b>
Enriched – Waste Inventory	430.6	7.3	345.1	1,870.2
Normal – Waste Inventory	13.2	<0.1	0.9	0.4
Depleted – Waste Inventory	867.0	0.1	13.7	50.3
<b>Total – Waste Inventory</b>	<b>1,310.8</b>	<b>7.5</b>	<b>359.7</b>	<b>1,920.9</b>

### 3.2.2 RMI

The constituent receipt and shipment information for RMI has been developed utilizing historical data and information from the Material Control and Accountability System as documented in Section 3.1.2, recycled uranium receipts and shipments. The recycled uranium data were carefully analyzed and using process knowledge, representative constituent value ranges determined based on data sources and subgroups presented in Table ES-5B. Using the data from the tables presented and discussed above, the FEMP Recycled Uranium Project team developed a detailed spreadsheet which quantifies the “Calculated mass constituents” for Pu-239, Np-237 and Tc-99 for all normal, depleted and enriched shipment of recycled uranium at the FEMP. This spreadsheet is presented in detail in Appendix F, Tables F.5-2A and F.5-2B, summarized below.



**TABLE 3-2B**  
**RMI SUMMARY OF CALCULATED CONSTITUENT MASSES**

Isotopic Range	RU Quantity (MTU)	Calculated Constituent Mass (Grams)		
		Pu-239	Np-237	Tc-99
Enriched – Receipts	25,327.4	108.8	9,422.6	178,542.0
Normal – Receipts	5,236.0	0.5	351.3	139.0
Depleted – Receipts	46,158.5	0.3	117.2	421.0
<b>Total – Receipts</b>	<b>76,721.9</b>	<b>109.6</b>	<b>9,891.1</b>	<b>179,102.0</b>
Enriched – Shipments	25,269.8	108.6	9,401.1	178,135.9
Normal – Shipments	5,181.8	0.5	347.6	137.6
Depleted – Shipments	45,722.7	0.1	25.0	89.9
<b>Total – Shipments</b>	<b>76,174.3</b>	<b>109.2</b>	<b>9,773.7</b>	<b>178,363.4</b>
<b>Total – NM Inventory</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
<b>Total – Waste Inventory</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>

### 3.2.3 WVDP

There were no constituent receipts at the West Valley Facility because Spent Fuel is not considered in the scope for this project. There are no analytical records available at the West Valley Site that describe the contaminants contained in these shipments, only records that indicate the U-235 and U-238 content. An analysis for the constituents of concern in the shipments of recycled uranium in the form of liquid uranyl nitrate has been developed using analytical results for UNH shipped to FEMP by the Savannah River Site. Table 3-2C presents that information.

**TABLE 3-2C**  
**WVDP SUMMARY OF CALCULATED CONSTITUENT MASSES**

Isotopic Range	RU Quantity (MTU)	Calculated Constituent Mass (Grams)		
		Pu-239	Np-237	Tc-99
<b>Total – Receipts</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
Enriched – Shipments	464.4	1.8	64.6	1,465.2
Normal – Shipments	12.9	0.1	1.8	40.7
Depleted – Shipments	142.1	0.6	19.8	448.3
<b>Total – Shipments</b>	<b>619.4</b>	<b>2.5</b>	<b>86.2</b>	<b>1,954.2</b>
<b>Total – NM Inventory</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
<b>Total – Waste Inventory</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>

<sup>a</sup> This analysis does not include approximately MTU of ~90% U-235 bearing solutions sent in 1967 and 1968 to the Y-12 Plant at Oak Ridge.



### 3.2.4 WSSRAP

The constituent receipt and shipment information for WSSRAP has been developed utilizing historical data and information from the Material Control and Accountability System as documented in Section 3.1.2, recycled uranium receipts and shipments. The recycled uranium data were carefully analyzed and using process knowledge, representative constituent value ranges determined based on data sources and subgroups presented in Table ES-5D. Using the data from the tables presented and discussed above, the FEMP Recycled Uranium Project team developed a detailed spreadsheet which quantifies the "Calculated mass constituents" for Pu-239, Np-237 and Tc-99 for all normal, depleted and enriched shipment of recycled uranium at the FEMP. This spreadsheet is presented in detail in Appendix F, Tables F.5-4A and F.5-4B summarized below.

**TABLE 3-2D**  
**WSSRAP SUMMARY OF CALCULATED CONSTITUENT MASSES**  
**FOR RECEIPTS/SHIPMENTS/INVENTORY**

Isotopic Range	RU Quantity (MTU)	Calculated Constituent Mass (Grams)		
		Pu-239	Np-237	Tc-99
Enriched – Receipts	842.6	2.4	327.7	7,206.1
Normal (Natural) – Receipts	70,538.4	--	--	--
Depleted – Receipts	32.0	0	0.1	0.3
<b>Total – Receipts</b>	<b>71,413.0</b>	<b>2.4</b>	<b>327.8</b>	<b>7,206.4</b>
Enriched – Shipments	833.9	2.4	324.4	7,131.7
Normal (Natural) – Shipments	73,878.4	--	--	--
Depleted – Shipments	92.3	0	0.2	0.8
<b>Total – Shipments</b>	<b>74,804.6</b>	<b>2.4</b>	<b>324.6</b>	<b>7,132.5</b>
<b>Total – NM Inventory</b>	--	--	--	--
<b>Total – Waste Inventory</b>	--	--	--	--

### 3.3 SITE INVENTORY OF RECYCLED URANIUM AS OF MARCH 31, 1999

The four sites addressed in this Ohio Field Office Recycled Uranium Project report are believed to have received, during their operational history, recycled uranium materials that had been irradiated in one of the DOE production reactors. These sites are also currently performing environmental restoration and waste management activities associated with the decommissioning and closure of the sites. Three of the sites addressed in this report, RMI, Weldon Spring, and West Valley, provided information that indicates that all recycled uranium materials and wastes had been removed from their site prior to the March 31, 1999 requested inventory status date. The remaining site, the FEMP, is currently implementing a variety of remedial actions designed to achieve site closure by FY-2008.



### 3.3.1 FEMP Site Inventory of Recycled Uranium as of March 31, 1999

The FEMP served as the DOE feed materials production center from the early 1950s through 1989. As discussed above, the FEMP received, shipped, and processed uranium products from 1961 through 1989 that used recycled uranium feed stocks containing constituents of concern. Since the curtailment of operations in 1989, the FEMP has been actively involved in DOE Environmental Management funded environmental restoration and waste management activities. These activities have included the completion of remedial investigation activities required for NPL listed sites, the completion of remedial design activities, and the initiation of remedial actions necessary to allow site closure. Two significant activities that have been ongoing since the termination of FEMP production operations are the management and disposition of low level and mixed radioactive wastes and the management and disposition of residual uranium materials (product) that could be useful to future DOE operational missions. As a result, the FEMP continues to have an inventory of both recycled uranium wastes and product that must be accounted for and evaluated to ascertain its contribution to the complex wide mass balance.

#### FEMP Waste Inventory

The FEMP Waste Inventory data follows this discussion as Table 3-3A. The data used to create this table were derived using a report-specific query to obtain historical data from the FEMP Sitewide Waste Information, Tracking and Reporting System (SWIFTS) database. The query was constructed to identify all waste containers generated on or before March 31, 1999 (Waste Production Date  $\leq$  03-31-1999) with an "Active" status (Status = Active). Therefore, this query provided the population of waste containers generated on or before March 31, 1999 that remain in storage at the FEMP site. The data generated by this query were then transferred to Microsoft Excel spreadsheet software for data treatment and reporting purposes.

Unique data treatment included removal of all thorium waste containers (identified with a "T" classification code or a "Txxx" production order number code), since thorium wastes/materials are not within the scope of this study. In addition, all non-waste materials currently being managed by the Nuclear Materials Disposition (NMD) Project were also removed from consideration, since other data sources were available for the evaluation and reporting for these "product" materials.

The remaining data set was subdivided into three distinct populations (Depleted, Normal, and Enriched) based upon Uranium enrichment concentrations. These categories were further divided into distinct groups based upon Material Type Code designations or individual group assignments based upon projects





responsible for waste generation. Spreadsheet manipulation functions, e.g. count, sum, min, and max, were then used for each data range to create the numeric values as presented in Appendix G.

For the purposes of the development of the recycled uranium report, the FEMP has assumed that material and wastes resulting from production operations after 1961 contain recycled uranium and the constituents of concern.

The FEMP March 31, 1999 inventory of recycled uranium waste materials is presented in Table 3-2A and consists of a variety of waste types and materials. The majority of the waste materials are either uranium metals (wastes), miscellaneous residues, mixed waste residues, contaminated soils,  $U_3O_8$  (mixed waste and material),  $UF_4$ , or  $UO_3$ . A more detailed breakout is included in Appendix F. The calculation and quantification of estimated values for the contaminants of concern contained in the FEMP waste inventory is also presented in Appendix F of this report.

#### FEMP Nuclear Material Inventory

Following the cessation of production operations at the FEMP, approximately 13,670 MTU of nuclear materials require disposition as either product (useable material) or as waste material. Since the process of dispositioning of this material began in 1989, approximately 11,000 MTU of nuclear materials have been dispositioned. Table 3.11 presents the FEMP recycled uranium inventory of nuclear materials remaining on-site as of March 31, 1999. Not included in this table are approximately 1,246 MTU of depleted, normal, and enriched non-recoverable residues that are considered as wastes and, as such, addressed in the FEMP waste inventory discussed above.

The quantity of nuclear materials in inventory was compiled using the FEMP MC&A records as presented in the monthly Fernald uranium inventory position report. This report is published monthly and serves as the site's primary document to status the Nuclear Materials Disposition Project efforts to disposition the residual nuclear inventory. The April 1, 1999 Uranium Inventory Position memorandum is included in Appendix G.

As presented in Table 3-1A, on March 31, 1999 the FEMP had slightly more than 3,801 MTU of depleted, normal, and enriched nuclear materials. As previously mentioned in the discussion of the FEMP waste inventory, for the purposes of the development of the recycled uranium report, the FEMP has assumed that the majority, essentially 100 percent, of the material and wastes resulting from production operations after 1961 contains recycled uranium and the constituents of concern at the FEMP.



The calculation and qualification of estimated values for the contaminants of concern contained in the FEMP waste inventory is presented in Appendix F of this report. The following table provides a further breakdown of the nuclear materials inventory by material type:

**TABLE 3-3A**  
**FEMP RECYCLED INVENTORY AS OF MARCH 31, 1999**

Material	Material Type	Net weight	MTUs
Enriched	UO <sub>3</sub>	451,201	168.8
	UF <sub>4</sub>	134,017	45.1
	Metals	656,994	292.0
	Miscellaneous Materials	970,830	295.4
Total	Enriched	2,213,042	801.3
Normal	UO <sub>3</sub>	48	0.0
	UF <sub>4</sub>	14,174	4.6
	Metals	424,332	188.8
	Total	438,554	193.4
Depleted	UF <sub>4</sub>	4,281,501	1471.9
	Metals	2,944,179	1335.2
Total	Depleted	7,225,680	2807.1
Total	All Inventory	9,887,276	3801.8

### 3.3.2 RMI

There is no inventory of recycled uranium at the RMI facility as of March 31, 1999, which is shown on Table 3-1B. The facility is currently undergoing decommissioning and dismantlement.

### 3.3.3 West Valley

There is no material in inventory at the West Valley Facility that meets the criteria for this report and is shown in Table 3-1C.

### 3.3.4 Weldon Spring

There is no inventory of recycled uranium at the Weldon Spring facility as of March 31, 1999 as is shown on Table 3-1D. The facility is currently dismantled and being environmentally remediated.



### 3.4 MASS BALANCE ACTIVITIES

#### 3.4.1 Annual Mass Balances of Recycled Uranium

Table 3-4 on the following page provides a summary of the total receipts and shipments for the four sites included in this report. The records for the preparation of this table were not easily found. The table is within the bounds of the 5% accuracy expected for this report.

#### 3.4.2 Annual Mass Balances of Plutonium in Recycled Uranium

This information can not be prepared with the records currently available. The reason is that the factor used to calculate the constituents of concern are based on the materials and compounds being received and shipped. The MC&A records do not identify this information and therefore a summary table could not be prepared.

#### 3.4.3 Annual Mass Balances of Neptunium in Recycled Uranium

This information can not be prepared with the records currently available. The reason is that the factor used to calculate the constituents of concern are based on the materials and compounds being received and shipped. The MC&A records do not identify this information and therefore a summary table could not be prepared.

#### 3.4.4 Annual Mass Balances of Technetium in Recycled Uranium

This information can not be prepared with the records currently available. The reason is that the factor used to calculate the constituents of concern are based on the materials and compounds being received and shipped. The MC&A records do not identify this information and therefore a summary table could not be prepared.

#### 3.4.5 Mass Balance of Other Constituents, if any.

There are no other constituents of concern.



**TABLE 3-4**  
**ANNUAL MASS BALANCE OF RECYCLED URANIUM**

Year	FEMP Receipts	FEMP Shipments	RMI Receipts	RMI Shipments	WVDP Receipts	WVDP Shipments	WSSRAP Receipts	WSSRAP Shipments
1962	13,387.4	13,509.7	526.9	367.8	-	-	16,031.3	15,942.6
1963	17,929.0	15,423.0	2,977.6	2,817.7	-	-	18,968.1	16,894.0
1964	16,586.1	17,058.1	4,518.5	4,600.8	-	-	16,926.8	15,509.1
1965	12,022.8	13,302.0	2,213.0	2,217.0	-	-	11,890.0	5,706.8
1966	11,303.3	10,023.1	2,694.8	2,729.6	-	104.6	7,111.6	4,041.9
1967	24,413.1	10,374.0	3,249.3	3,267.4	-	133.7	485.2	16,710.1
1968	8,816.9	13,878.0	2,875.5	2,803.1	-	142.2	-	-
1969	8,201.7	7,669.9	2,657.3	2,533.5	-	119.7	-	-
1970	6,957.8	6,589.5	1,731.7	1,762.8	-	52.1	-	-
1971	4,138.7	5,113.0	1,920.3	1,916.4	-	67.0	-	-
1972	8,816.9	7,289.3	1,898.1	1,889.1	-	-	-	-
1973	7,190.3	10,925.0	3,083.4	3,072.9	-	-	-	-
1974	12,865.5	12,219.8	2,226.3	2,179.8	-	-	-	-
1975	10,416.1	10,383.4	1,547.3	1,492.9	-	-	-	-
1976	5,702.2	16,154.1	2,076.4	2,108.8	-	-	-	-
1977	10,260.8	7,095.0	2,232.4	2,251.5	-	-	-	-
1978	3,679.9	3,796.8	2,314.7	2,351.2	-	-	-	-
1979	1,889.9	3,260.7	2,355.2	2,312.9	-	-	-	-
1980	1,870.2	3,518.8	3,175.8	3,166.2	-	-	-	-
1981	3,753.6	4,528.6	3,794.5	3,720.9	-	-	-	-
1982	6,848.7	6,755.0	5,873.9	5,792.4	-	-	-	-
1983	7,755.9	8,084.0	6,619.1	6,319.5	-	-	-	-
1984	10,563.8	7,859.7	4,832.6	4,774.0	-	-	-	-
1985	8,494.3	6,540.8	3,697.7	3,957.3	-	-	-	-
1986	10,775.0	7,820.1	4,322.5	4,617.6	-	-	-	-
1987	8,956.3	4,639.4	801.6	524.3	-	-	-	-
1988	2,363.2	3,603.2	495.5	624.5	-	-	-	-
1989	43.7	1,847.4	9.7	2.2	-	-	-	-
1990	25.9	1,273.9	0.2	0.3	-	-	-	-
1991	32.5	1,519.0	0	0.1	-	-	-	-
1992	1.1	1,257.2	0	0	-	-	-	-
1993	53.4	1,675.8	0.1	0	-	-	-	-
1994	334.2	1,575.9	-	-	-	-	-	-
1995	112.6	351.6	-	-	-	-	-	-
1996	20.7	340.8	-	-	-	-	-	-
1997	7.4	38.3	-	-	-	-	-	-
1998	3.8	213.8	-	-	-	-	-	-
1999	0.2	1,721.8	-	-	-	-	-	-
Total	246,683.1	249,229.5	76,721.9	76,174.3	-	619.4	71,413.0	74,804.6